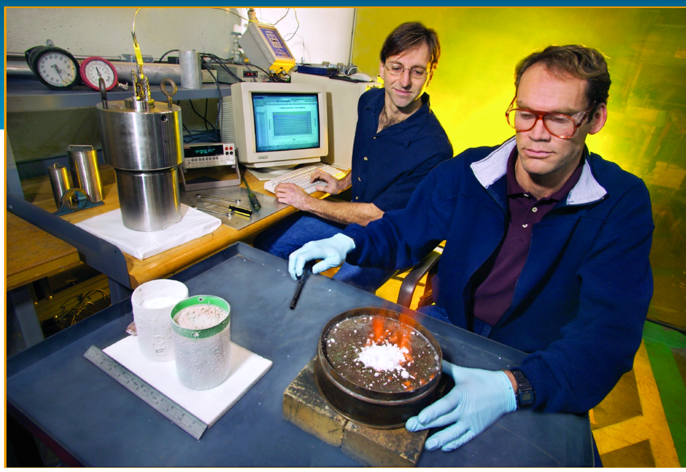

Resource Department

Hydrogeology and Reservoir Dynamics

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The Hydrogeology and Reservoir Dynamics (HRD) department consists of more than 60 scientists, postdocs, research associates, and graduate students carrying out a broad range of cutting-edge research in fundamental and applied hydrology. HRD has expertise in theoretical, experimental, field, and modeling approaches in a variety of research areas, among which are unsaturated zone hydrology (including fracture flow and transport), reservoir engineering (including pore-level modeling and gas hydrate studies), contaminant hydrology (including reactive and colloid-assisted transport), and coupled nonisothermal, geochemical, and geomechanical processes. The HRD department addresses national needs in the areas of subsurface energy resource recovery, contaminant hydrology, geologic CO_2 storage, and nuclear waste disposal. Highlights of research efforts in these areas over the last two years include the following:

SUBSURFACE ENERGY RESOURCE RECOVERY

Researchers in HRD are studying ways to enhance production of energy from subsurface reservoirs containing geothermal energ y, oil and gas, and methane gas hydrates. Continuing the long tradition of geothermal research in the Earth Sciences Division, staff members in HRD are investigating geothermal reservoir dynamics using natural tracers as indicators of boiling, recharge, and mixing in liquid-dominated systems. Applications and development of ESD's reservoir simulator TOUGH2, for phase-partitioning tracer studies using noble gases in vapor-dominated systems, are also carried out for characterizing fracture systems and fracture matrix interaction—with the ultimate goal of optimizing energy production. Imaging of oil reservoir rock and highly detailed mathematical models of pore structure are used by HRD scientists to derive relative permeability curves to improve oil recovery from rocks such as diatomite.

The vast potential of gas-hydrate deposits in permafrost, coupled with practical barriers to hydrate gas production, has motivated HRD's development of the world's leading gas-hydrate reservoir simulator. This extension of TOUGH2 has been used to predict gas production from a permafrost reservoir for various types of hydrate deposits. In a parallel effort, HRD researchers have developed the first-ever portable computed tomography (CT) scanner for imaging gas hydrates in rock cores that are brought to the surface during exploration drilling. This innovation has allowed researchers to quantify gas-hydrate deposits on site before dissociation of the hydrates occurs due to depressurization and heating. Laboratory experiments using CT scanning of manufactured hydrates in rock cores are allowing ESD researchers to track hydrate dissociation fronts over time while controlling pressure and temperature. This work will lead to better understanding of hydrate dynamics and gas-hydrate methane production strategies. Integrating scientific observations of gas hydrates from the field and lab, coupled with unique numerical simulation capabilities, creates an effective approach to gas hydrate science.

CONTAMINANT HYDROLOGY

HRD researchers address the national need for subsurface contaminant characterization and remediation across the spectrum of approaches. In the lab, HRD researchers are investigating some of the nation's most critical subsurface contamination issues, including the chemical evolution of highly alkaline Hanford tank waste, reduction and re-oxidation of mobile Uranium VI in sediments, hydraulic properties of unsaturated gravels, and the natural production of transport-enhancing mobile nanoparticles in the subsurface. In the field, HRD investigators lead the Berkeley Lab site restoration effort to remediate groundwater plumes containing dissolved chlorinated solvent and fuel contaminants. A pressurized constant-head water-injection system has been developed and used to measure hydraulic conductivity in low-conductivity systems typical of the Berkeley Lab site. Soil heating with vapor extraction was used in a low-permeability and heterogeneous setting to remove over 500 kg of chlorinated solvent. In addition, TOUGH2 modeling of groundwater flow at the Berkeley Lab site is being carried out to improve understanding of contaminant transport. HRD's work in surface water is growing: field work is being done to investigate the hydraulic conductivity of river gravels for recharge studies, and to develop and test a fiber-optic turbidity meter. Collaboration with scientists in other ESD departments and Berkeley Lab divisions is currently under way, with a focus on the coupled water-energy system in California. On the theoretical and modeling side, new TOUGH2 modules for multiple volatile organic compounds (TMVOC) and landfill biodegradation and gas production processes (T2LBM) have been developed. The pumping rates and pressures in deep well injection of hazardous waste have been analyzed with a new approach to obtain formation hydraulic properties. Finally, HRD maintains an international program to develop and test advanced technologies at sites worldwide, which can then be used domestically to help with our nation's most difficult contamination problems.

GEOLOGIC CO_2 STORAGE

A relatively new area in which HRD is making significant advances (with national and international impact) is geologic CO_2 storage. Because geologic CO_2 storage is a new concept, there are broad basic research needs. For example, HRD researchers are developing methods for predicting CO_2-H_2O mutual solubilities. These methods are then incorporated into new modules of TOUGH2 that are applied to a variety of CO_2 storage problems, including CO_2 injection into deep brine formations, injection into depleted gas reservoirs, leakage upward through faults and fractures, and leakage and seepage of CO_2 in the near-surface environment. The effects of geochemical processes, including mineral precipitation and dissolution associated with CO_2 storage, are being studied using TOUGH-REACT, the coupled geochemistry and reservoir simulator. By analogy, mechanical effects associated with CO_2 storage are being studied using TOUGH-FLAC, a coupled geomechanical reservoir simulator. An international code intercomparison study led by HRD researchers provided confidence that CO_2 reservoir processes can be accurately modeled. Laboratory work in this area has included efforts to image CO_2 flow and measure relative permeability parameters such as residual gas saturation, a key property for saturated zone CO_2 storage.

NUCLEAR WASTE DISPOSAL IN THE UNSATURATED ZONE

The motivation for HRD's extensive effort in unsaturated zone hydrology and coupled processes is stimulated by the need to understand flow and transport in the unsaturated zone at Yucca Mountain, Nevada. Research by HRD scientists in this prominent area is both broad and focused. Starting with research underground, HRD scientists have run a wide program of experiments and testing in the Exploratory Studies Facility (ESF) at Yucca Mountain. Field experiments range from the large multi-year Drift Scale Test, to smaller-scale liquid releases in boreholes. The practical difficulties of running tests underground at a remote site have motivated the development of sophisticated remote monitoring and operation capabilities, whereby instrument adjustments, liquid releases, and data collection can be controlled remotely by scientists on site at Berkeley Lab. In addition, a large block of fractured tuff (1 cubic meter) was extracted from the ESF and transported to Berkeley Lab for laboratory experiments and testing. This effort complements smaller-scale lab experiments focused on mineral precipitation and dissolution in fractured tuff by hot aqueous fluids. The heater testing, seepage experiments, and fault and fracture flow testing (among other tests) have been designed and run by teams that include members with numerical modeling expertise.

The coupled approach of field experiment and modeling analysis has served to advance understanding of the coupled flow and transport properties of Yucca Mountain. Field data are used to constrain and calibrate numerical models of flow and transport developed over a wide range of scales for Yucca Mountain. These efforts involve the use of the inverse modeling version of TOUGH2 called iTOUGH2, also developed by HRD personnel. On the mountain scale, a large three-dimensional TOUGH2 model has been developed, the flow fields from which are used with advanced transport modules that consider colloid-assisted transport and diffusion to model radionuclide transport. The details of seepage into drifts, flow diversion, and flow focusing are modeled on appropriate scales, as are processes of water-rock interaction and geomechanical effects.

A considerable amount of general unsaturated zone hydrology knowledge and understanding is generated by HRD researchers. For example, new conceptualizations of fracture-matrix interaction, scale dependence, and effects of multiscale heterogeneity have been investigated. Work in this area also extends to saturated systems in Japan, where free convection simulations and uncertainty studies associated with potential nuclear waste repositories are being carried out. The large effort in HRD on a broad range of hydrologic processes related to nuclear waste disposal typifies the strong integration of field, laboratory, and modeling analyses characteristic of ESD scientific investigations.

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